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The Characteristics of Deep-Sea Epifaunal Megabenthos Community Two Years After an Artificial Rapid Deposition Event

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Abstract The Japan Deep-Sea Impact Experiment (JET) was carried out in the summer of 1994, at the central Pacific Ocean, to test the effects of rapid artificial deposition, supposed to occur during future commercial mining. As a part of this experiment, the abundance of megabenthos was compared between areas where sediment plume arrived two years ago (DA) and a control area not disturbed (NDA), using the finder-installed deep-sea video camera system (FDC). The densities of total megabenthos, motile species and deposit feeders were significantly lower in DA than in NDA. Within dominant taxonomic groups, holothurians, which were typical deposit feeders, were significantly less in DA than in NDA. On the other hand, the densities of sponges and ophiuroids were not different between the two areas. The observed difference suggests that the deposit feeders were sensitive whereas suspension feeders and omnivores were resistant to the artificial disturbance. The tendency can be explained if one notice that the food environment for deposit feeders remained disturbed for a long time, but that for suspension feeders and omnivores were restricted during the period of the experiment.

Key words: Environmental Conservation, Deep-Sea, Megabenthos, Manganese Nodules, Marine Mining

Introduction

In the 1960s, considerable attention began to be paid to the abyssal seafloor of the central Pacific Ocean with respect to its potential as a source of mineral ores (Mero, 1960). From that time, a hydraulic collector system similar to a large vacuum cleaner (Burns and Suh, 1979) was considered to be the most likely system to be employed in the first generation of nodule mining operations (Handa *et al.*, 1982). Though such a system was expected to be efficient, it would inevitably make sediment plume, that may seriously impact on the benthic organisms inhabiting the mining area.

Studies have been done to evaluate the environmental impact associated with manganese nodule mining, *e.g.* DOMES and BIE by NOAA (Trueblood and Ozturgut, 1997) and DISCOL by Germany (Schriever, 1995). Metal Mining Agency of Japan (MMAJ) conducted the Japan Deep-Sea Impact Experiment (JET) in 1995–1997 (Fukushima, 1995) using a similar design to BIE to simulate the impact of deep-sea mining. Furthermore, similar experiments were also currently being conducted, *e.g.* IOM BIE (Radziejewska and Modlitba, 1999) and INDEX (Sharma, 1999). Most studies except DISCOL focused on the

impact of sediment redeposition resulting from sediment clouds release by the mining collectors. And in those projects, macro- and meiobenthos were selected as biological indicators, however megabenthos were not studied well, because quantitative sampling of the former can be done using rather inexpensive gear such as multiple corer, while it is prerequisite to prepare very expensive specific gear such as deep-sea camera system to study the latter.

Generally speaking, the population density of megabenthic community is so low that it is almost impossible to survey by a sediment sampler (Christiansen and Thiel, 1991). However it is thought to be one of the major component in the material flow *e.g.* sediment mixing, transportation of dissolved oxygen of the deep-sea ecosystem (Smith and Hamilton, 1983; Gage and Tyler, 1991; Bluhm *et al.*, 1995). Furthermore, megafauna is hypothesized to play a key role for structuring the high diversity of small benthic fauna by creating an unstable situation in time and space (Tyler, 1995).

In addition, the ecological guild of megabenthos is different from those of the meio- and macrobenthos. Therefore, the impacts due to mining on megabenthos should be different from meio- and macrobenthos (Jumars, 1981). The major aim of this study is to address the impact of the artificial rapid deposition on megabenthos community.

Survey site and disturbance process

Observation of megabenthos was carried out from September 19 to 21, 1996, during the fourth cruise of the Hakurei-maru No. 2 of the Metal Mining Agency of Japan, in the area around 9°14'N, 146°15'W at a depth of approximately 5,300 m (Fig. 1). At this site, the artificial sediment plume was made from August 27 to September 20, 1994 using a benthic disturber (Barnett and Yamauchi, 1995; Fukushima, 1995). This instrument, disturbed sediment with a fluidizing pump, sucked up the sediment with a lift-up pump, and then discharged it from a 4-meter-high chimney in and around the study area (Barnett and Yamauchi, 1995; Fukushima, 1995)(Fig. 2). It was towed on parallel courses from northeast to southwest for 2,000m. Two concentrated areas were designed, i.e. the southern (track#1; 150m in width) and the northern track (track#2; 110m). They were separated by a 100m broad area (Fukushima, 1995)(Fig. 3). The towing of the benthic disturber was replicated 20 times. Approximately 352 tons of sediment were estimated to be discharged (Barnett and Yamauchi, 1995), and the suspended sediment traveled up to 500m (Yamazaki *et al.*, 1997).

Methods

Observation of sea bottom by video camera

The finder-installed deep-sea camera (FDC) was used for observations of megabenthos. It consisted of a video camera, a still picture camera, a CTD and a pinger, mounted on a frame. It was towed by a wire incorporating an optical fiber cable. During the observation, to maintain 3-m width of coverage area, the assembly was towed trying to keep a constant distance of about 3-m above the sea bottom. Towing velocity was about 1 knot. Towing direction was from the northwest to the southeast, perpendicular to the tracks of the disturber. Observations were made along five observatory lines set at constant intervals from the center of the disturbance area to the northeastern end (Fig. 3).

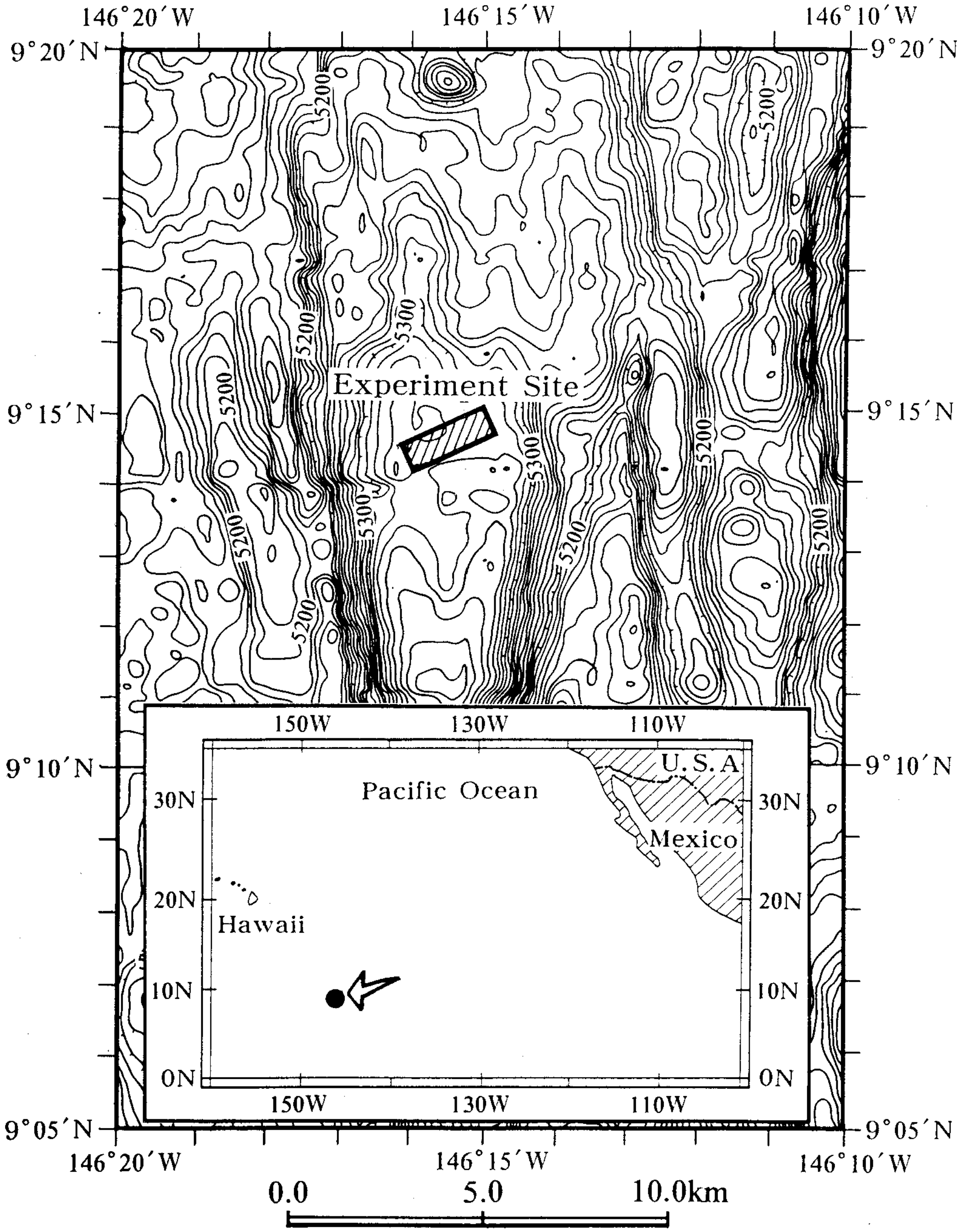


Fig.1. Location map and topography of the Japan Deep-Sea Impact Experiment site (after Fukushima, 1995).

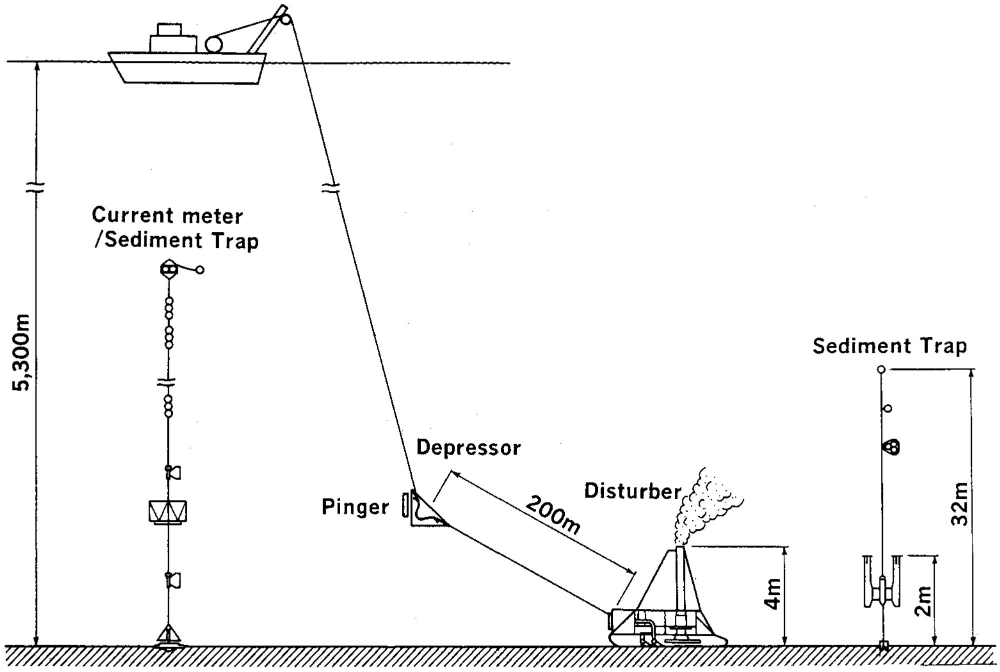


Fig.2. Schematic arrangement for disturber towing (after Fukushima, 1995).

Data processing

In the present paper, only epifaunal megabenthos is considered. Drifting or swimming organisms such as Osteichthyes, Crustacea and Polychaeta were excluded in the quantitative data. Xenophyophorea also was excluded from the abundance data, because it is high variation in size and shape (Levin and Gooday, 1992), so that the error of observation was likely to large. The abundance of megabenthos (inds./ha) was estimated from the number of organisms and the size of observed areas. The organisms were counted from the video recording and the size of observation areas were calculated by width of covered area multiplied observed length.

The observed organisms were divided into suspension feeders, deposit feeders and others, and each group was subdivided into major taxonomic groups. The suspension feeders defined in this study, were Porifera, Actinaria, Crinoidea and Pennatulida, while the deposit feeders were Holothuroidea and Lophenteropneusta.

Results

The FDC was towed for a total of 17.13 km (Table 1). From the photographic data, the observed area was divided into two areas, i.e. the no deposition area (NDA) where sediment did not cover manganese nodules and the deposition area (DA) where deposition was observed on the surface of nodules (Fig. 4). The distance of the former was 10.36 km, and the latter was 6.77 km.

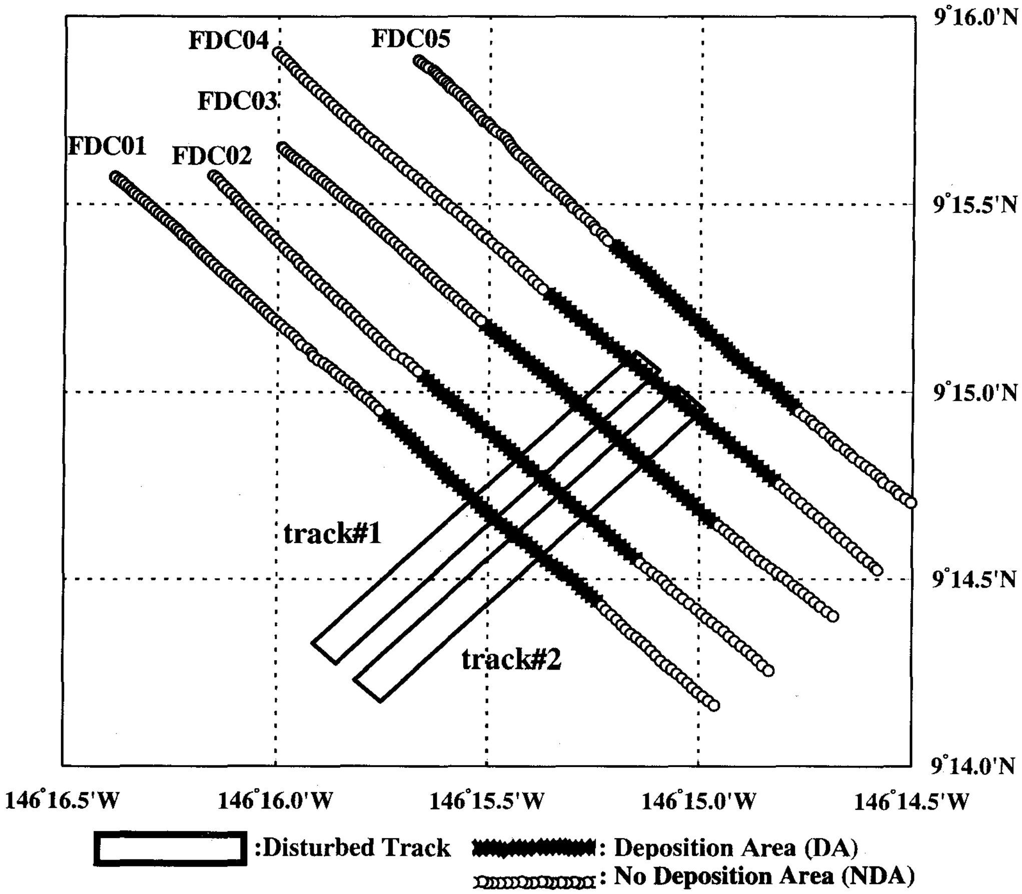


Fig.3. The locations of the 5 FDC (Finder-installed Deep-sea Camera) survey lines in the JET 4 cruise.

Table 1. Distance of FDC observation line (km).

Line	NDA	DA	Total
FDC 01	2.42	*1.26	3.68
FDC 02	2.05	1.34	3.39
FDC 03	1.83	*1.48	3.31
FDC 04	2.21	1.39	3.60
FDC 05	1.85	1.30	3.15
amount of distance	10.36	6.77	17.13
applicable obsevation	10.36	4.03	14.39

* : not applicable observation

Table 2. Identified taxa, life habitat and feeding habitat.

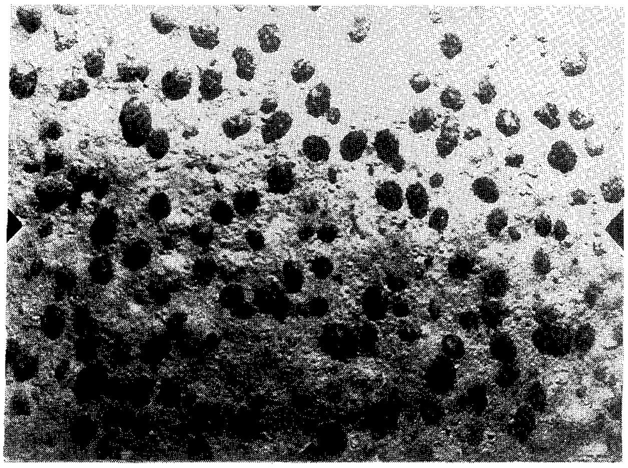
Phylum	Taxa	Life habitat	Feeding habitat
Protozoa	Xenophyophorea	SE	SU
Porifera*		SE	SU
Cnidaria	Pennatularia*	SE	SU
	Actiniaria*	SE	SU
Annelida	Polychaeta	MO, SE	OT
Arthropoda	Crustacea	MO	OT
Echinodermata	Crinoidea*	SE	SU
	Comatulida*	SE	SU
	Holothuroidea*	MO	DE
	Ophiuroidea*	MO	OT
	Asteroidea*	MO	OT
Hemichordata	Lophenteropneusta*	MO	DE
Vertebrata	Osteichthyes	MO	OT

* Megabenthos taxa apply to quantitative abundance data
Life habitat: SE: sessile fauna, MO: motile fauna
Feeding habitat: SU: suspension feeder, DE: deposit feeder, OT: others

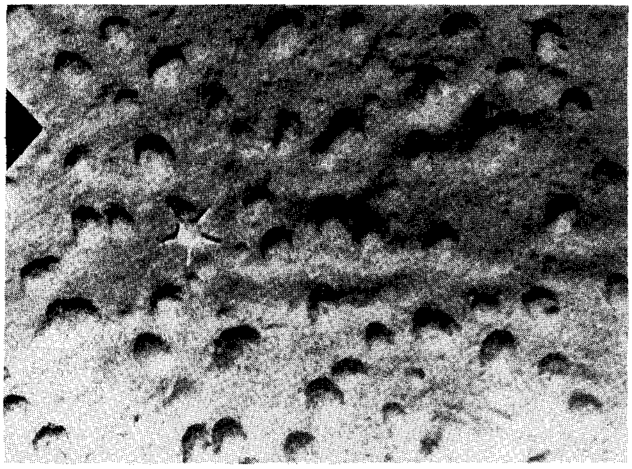
Throughout the observations, Xenophyophorea, Porifera, Actinaria, Pennatulida, Crinoidea, Holothuroidea, Ophiuroidea, Asteroidea and Lophenteropneusta were recognized (Table 2). Various types of sponge, such as stalked-, cushion- and cylindrical-type were observed. Among them, stalked type was the most abundant. Some individuals of starfish and holothurians were identified in genus or species level, *e.g. Freyella* sp., *Psychropotes longicaudata, Amperima* or *Peniagone* sp. and *Synallactes* sp.

In addition to above, drifting or swimming organisms such as Polychaeta, Crustacea and Osteichthyes were also observed. Due to overexposure, some of the smaller animals that strongly reflected the floodlights of the FDC appeared only as white spots were unable to be identified. Beside organism, many types of trails were also observed, the most abundant crawling trails were a smooth zigzag type similar to a snake trail (hereafter plough trail) and pinnate trail. Young *et al.* (1985) assumed that holothurians made plough trails, and pinnate are trails to the fin trace of bottom-feeding fish or moving trace of sea urchins. In the present study area, holothurians was one of the dominant faunal groups, while bottom-feeding fish or sea urchins were not observed. Therefore, the origins of the latter type trails were uncertain in this study.

Average abundance of the total epifaunal megabenthos in NDA was 139±20 inds./ha (Average±SD). Within those, sessile fauna was 35±20 inds./ha and motile fauna 72±22 inds./ha (Fig. 5). On the other hand, suspension feeders such as sponge, actinarians, pennatulids and crinoids was 42±8 inds./ha, while deposit feeder such as holothurians and Lophenteropneusta was 20±2 inds./ha (Fig. 6). Sponge, holothurians and ophiuroids were dominant taxonomic groups in NDA, and the abundance of them were 32±11 inds./ha, 20±3 inds./ha and 47±22 inds./ha respectively (Fig. 7).



No Deposition Area (NDA)



Deposition Area (DA)

Fig.4. Seabed photographs of the No Deposition Area (NDA) and the Deposition Area (DA) (after MMAJ, 1994).

In the disturbed area, average abundance of total epifaunal megabenthos was 123±20 inds./ha, sessile fauna was 36±4 inds./ha and motile fauna 42±2 inds./ha (Fig. 5). The abundance of suspension feeder in DA was 33±9 inds./ha and accounted for 78% of NDA, while deposit feeder 9±5 inds./ha and 46% (Fig. 6). Same as in NDA, sponge, holothurians and ophiuroids were dominant taxonomic groups in DA (27±1 inds./ha, 8±4 inds./ha, and 31±3 inds./ha, respectively). The abundance of sponge in DA accounted for 69% of the figure in NDA. Ophiuroids and holothurians also were less in DA than in NDA (Fig. 7). From the statistical point of view, the significant differences between DA and NDA were observed in the abundance of total megabenthos, motile fauna, deposit feeders and holothurians (t-test, $p<0.05$) (Figs. 5, 6, 7).

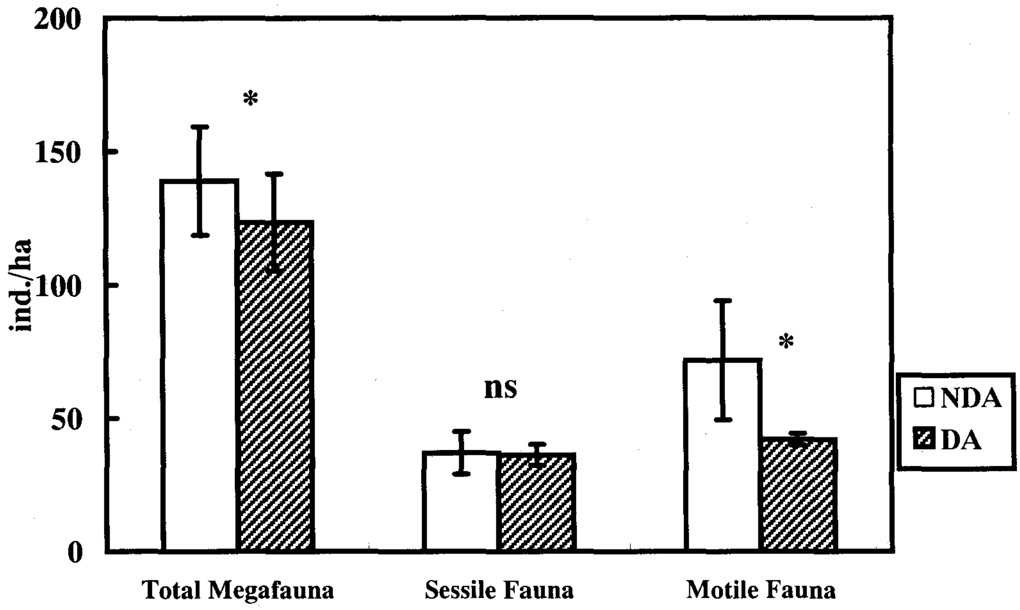


Fig.5. Abundance of total number of epifaunal megabenthos, sessile fauna and motile fauna in NDA and DA. Difference was tested by *t*-test. ns: not significant, *: $p<0.05$

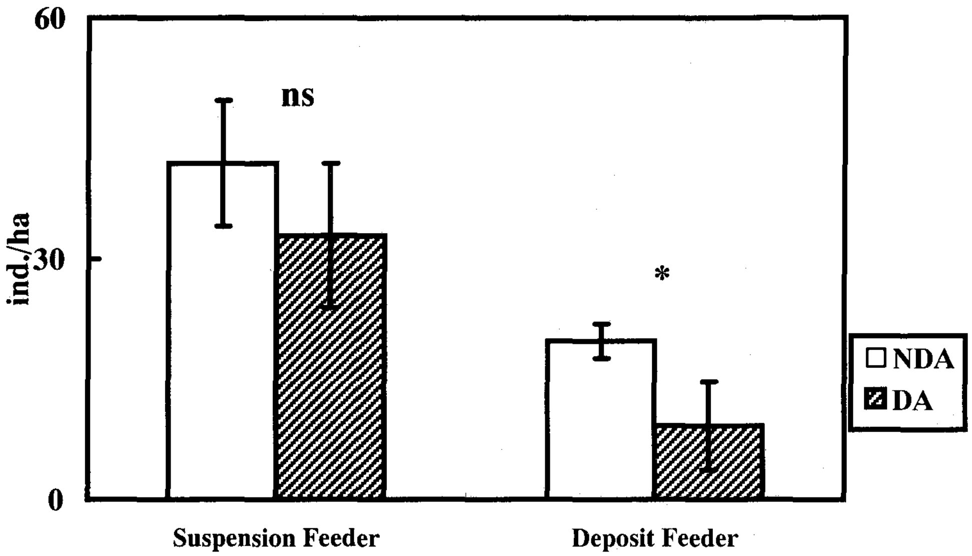


Fig.6. Abundance of suspension feeder and deposit feeder in NDA and DA. Difference was tested by *t*-test. ns: not significant, *: $p<0.05$

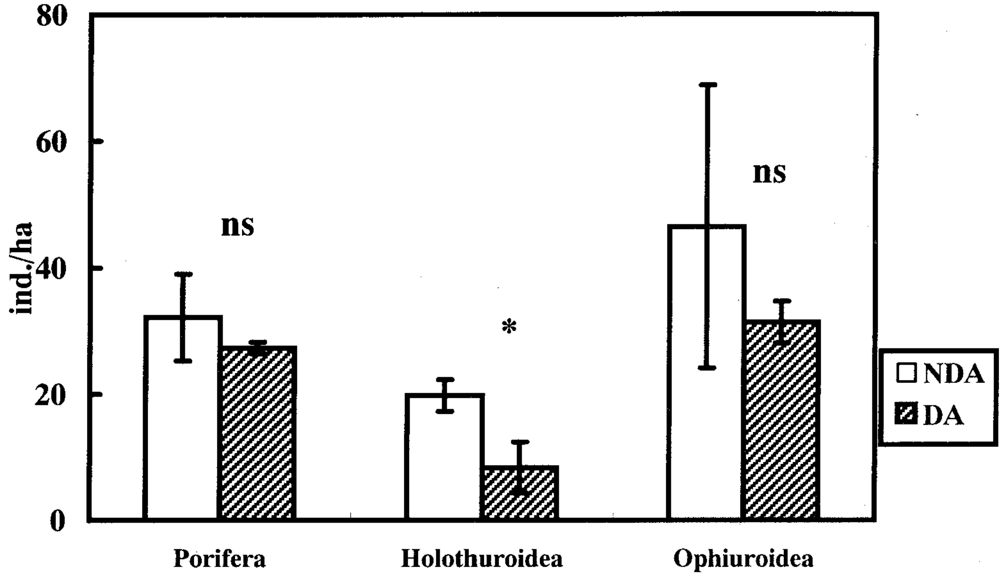


Fig.7. Abundance of Porifera, Holothuroidea and Ophiuroidea in NDA and DA. Difference was tested by *t*-test. ns: not significant, *: $p<0.05$

Discussion

(1) Impact on the megabenthos community

Although the artificial deposition event occurred two years before, significant differences between DA and NDA were found in the abundance of total megabenthos, motile fauna, deposit feeders and holothurians. The possible explanations are 1) there were, originally, the environmental difference which effect on the abundance of megabenthos, or 2) the effects of artificial disturbance caused by the benthic disturber has been continued for two years. As no pre-disturbance survey was undertaken, we could not directly assess the artificial impact, however from the results of other study subject, it is possible to make some inferences. The abundance of meiobenthos did not change widely from place to place in the pre-disturbance condition (Kaneko *et al.*, 1997). Moreover, the concentration of total organic carbon in DA in two years after the experiment was still significantly lower than in NDA (Harada and Fukushima, 1997). Given to these results, the heterogeneity of megabenthos distributions were likely to attribute to the artificial disturbance conducted in two years ago.

(2) Impact Mechanism

The sediment plume yielded by the benthic disturber was considered to disappear within several days after the operation (Doi *et al.*, 1999). On the other hand, concentration of total

organic carbon in the sediment surface of deposition area remained lower than in the control area even two years late (Harada and Fukushima, 1997). This result strongly suggests that the trophic condition for suspension feeders returned to the original situation quickly, however that for deposit feeders remained worse for two years. If such negative effects were large and persistent enough, that will lead to decrease food availability and reproductive potential, and to increase mortality of deposit feeders (Jumars, 1981).

Holothurians are typical deposit feeders, and were recognized to decrease its abundance after artificial disturbance. On the other hands, sponges are typical suspension feeders, and maintained the same density level. Most ophiuroids are omnivores (Pearson and Gage, 1984). The taxon, however, has a variety of feeding styles, *e.g.* suspension, surface deposit, deposit, passive suspension - feeding and scavenging (Fujita, 1988). It should be noticed that this taxon also kept the same levels of their abundance.

Strong correlationship between feeding ecology and tolerance to the artificial rapid deposition suggest that the decrease in the concentration of organic carbon of the sediment surface due to the artificial dilution adversely impacted solely on deposit feeders such as holothurians. However, for suspension feeders such as sponges, the impact due to redeposition was not serious because their main food sources were floating in the water column. In the case of omnivore, such as ophiuroids, they could select the food source from both suspended matter and depositions. Therefore, they were not damaged seriously.

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